

LINK INTEGRITY DUALITY FOR NETWORK DEVICES IN COLD POWER STATE

5 The present invention claims priority from U.S. Provisional
Application No. 60/183,520, entitled "Link Integrity Duality For In-Home
Phoneline Networking Transceivers", by Bullman, Holmqvist, Henry and
Strauss, filed February 18, 2000, the entirety of which is expressly
incorporated herein by reference.

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BACKGROUND OF THE INVENTION

1. Field of the Invention

15 This invention is directed to the field of networks. More
particularly, it relates to apparatus and techniques for network devices
such as networks which utilize a data based link integrity protocol, e.g., In
Home networks.

2. Background of Related Art

20 Networking, and in particular Home Networking (e.g., home
phone line networking based on specifications from HomePNA™) is a
new segment of the networking marketplace that is poised for rapid
growth. However, achieving the goals needed to make home networking a
market success is a challenging task. Nascent home networking market
growth will depend on the emergence of high-speed broadband access as
25 a catalyst as well as the availability of robust, low cost, easy to install
standardized home networking equipment.

30 Networks may include many devices of various types (e.g.,
Ethernet, 802.11, HomePNA, BLUETOOTH, power line networks such as
Homeplug™, etc.) and may or may not include wireless devices. Many
network devices power down from time to time, depending upon the

particular application. The health or presence of any particular network device is often determined using a link integrity function.

The purpose of any network link integrity function is to allow one network device to detect the health or presence of another network device. Events triggered by the receipt of a valid link integrity signal typically include, e.g., lighting an available system LED. The link integrity action is therefore very beneficial to a user, e.g., by providing a visual indication that the network is functioning properly. In a two-device network, a visual indication indicating a "good" network transitioning into an inactive state (not lit) due to one of the network devices entering a power conserving mode such as a D3 power down state is likely to lead to consumer confusion.

Initial link integrity functions utilized physically unique signaling on a wired line (e.g., Ethernet devices) to signal link integrity. However, in a growing number of network applications, link integrity is being handled in data based link integrity data packets transmitted over a communication link, instead of providing a unique electrical signal.

It is a general requirement of many such network devices to implement a link integrity function to ensure that, with high probability within some periodic interval, there is either (1) at least one link packet such as a link integrity control frame (LICF) sent to the Broadcast MAC address from the relevant station, or (2) at least one packet addressed to the Broadcast MAC address received from each of at least two other stations.

Fig. 5 shows a conventional data-based link integrity module incorporated within core memory of a network device, in accordance with the principles of the present invention.

In particular, as shown in Fig. 5, a network device **550** includes a core processor **502** (e.g., processor, microprocessor, or digital signal processor), core memory **504**, a link interface **506**, and a power

mode control module 508 (which may alternatively be integrated within the core processor 502 and/or the core memory 504). As depicted in Fig. 5, the core memory 504 includes a driver or other implementation of a software link integrity module 510.

5 Using the data based link integrity techniques, a software driver is typically loaded into a processor (e.g., a core CPU) to handle link integrity functions, either in response to an external request, or to itself report its health and/or presence. The software driver technique determines whether or not a particular network device is able to receive
10 frames from at least one other device on the network. In the absence of other traffic, the network device will periodically transmit, e.g., a Link Integrity Control Frame (LICF) to a Broadcast Media Access Control (MAC) address.

 For instance, in the emerging Home Phoneline Network
15 Alliance (HomePNA) Version 2.0 (V2) specification, link integrity is defined as a valid Ethernet packet-based approach periodically sent out in a defined frame format at a system negotiated encoding rate. Because system parameters can change as the quality of the channel changes, the encoding rate tends to be dynamic.

20 For instance, the Advance Configuration and Power Interface (ACPI) standard defines various power states that PC-centric devices must operate in, including a D3 cold state. In the D3 cold state, power is fully removed from the particular device at the system level. However, when power is removed, the device context is lost and thus no
25 driver remains present.

 Bound by this criteria, a link integrity function is easily performed by driver level code. However, the drivers must be maintained by the supporting network device for the link integrity function to be performed. Because of this, network devices using data based link
30 integrity typically do not transition to a power down state.

Accordingly, link integrity is not supported in a network device which relies on data based link integrity functionality when the network device enters a D3 cold state. To support link integrity, such devices must first power up from the D3 cold state, first reinstalling the pertinent link integrity driver(s). Typically, to provide link integrity as many specifications require (e.g., HomePNA version 2.0), the D3 cold state in such devices is conventionally avoided.

The current method defined in the HomePNA V2 specification for link integrity is a packet-based approach sent at the highest priority class of service. A minimum payload encoding (PE) value is negotiated and each station is required to send out the link integrity packet with a determined packet format at this negotiated PE value.

While this conventional approach is adequate when the system is in a functional and fully operational state, problems exist during the ACPI-defined power down states. In the context of ACPI, a "fully operational state" is defined as a non-D3 power state. In the fully operational state, the device is completely active and responsive, and is expected to continuously retain all relevant context information. However, when in a D3 power state, power is fully removed from the device. Unfortunately, device context is lost when this non-powered state is entered, and thus any/all software drivers that were present will be lost. Thus, while in a non-powered or D3 state, network device context information such as data, software drivers, etc., are lost, and thus network devices in this state certainly do not decode their network address lines, causing problems with respect to conventional software based link integrity techniques. After power is returned to the network device, the operating system (OS) will be required to reinitialize the network device, and relevant drivers will be reloaded.

Network devices in a D3 type cold state will typically require a relatively long restart/restore time to return to a functional state capable

of handling link integrity functions. Therefore, latency time is significant if a network device is to be woken up from a D3 type cold state to handle link integrity functions. This becomes problematic when a fully functional node in a network needs access to another device in the network that is

5 currently in a D3 cold (i.e., un-powered) state.

There is a need for an approach that allows the provision of a link integrity function while a network device is in a D3 type cold state.

SUMMARY OF THE INVENTION

10 In accordance with the principles of the present invention, a network device comprises a core processor and core memory. A link integrity module is in communication with the core processor. The link integrity module is powered separately from the core processor and the core memory. The network device includes a D3 type cold power mode

15 wherein the link integrity module maintains power.

A method of maintaining data-based link integrity in a powered down network device in accordance with another aspect of the present invention comprises providing a link integrity module powered separately from core functionality in the network device. Power is

20 removed from the core functionality of the network device while power to the separately powered link integrity module is maintained.

A method of providing both physical and data-based link integrity capability in a network in accordance with yet another aspect of the present invention comprises determining if another network device in

25 the network requires physical link integrity signaling. If another network device in the network requires physical link integrity signaling, a data-based link integrity packet is output in a physical link integrity mode. If no other network device in the network requires physical link integrity signaling, a data-based link integrity packet is output in a non-physical link

30 integrity mode.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

5 Fig. 1 shows a separately powered hardware link integrity module which remains powered when the network device is powered down, e.g., in a D3 type cold power state, as well as a software link integrity module in core memory which is lost during a power down, either of which are switched in as desired, in accordance with the principles of
10 the present invention.

Fig. 2 is similar to Fig. 1 but shows implementation of only the separately powered hardware link integrity module which remains powered when the network device is powered down, in accordance with another embodiment of the present invention.

15 Fig. 3 is an exemplary system behavior state flow diagram of the embodiment shown in Fig. 1.

Fig. 4 is an exemplary transmitter behavior state flow diagram showing backwards compatibility with a physically unique electrical signal based link integrity system (e.g., HomePNA version 1.0)
20 in a network device implementing data-based link integrity (e.g., HomePNA version 2.0), in accordance with the principles of the present invention.

Fig. 5 shows a conventional data-based link integrity module incorporated within core memory of a network device, in accordance with
25 the principles of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In accordance with the principles of the present invention, a data-based software type link integrity module is implemented separately
30 in hardware (e.g., using physical gates, using a microcontroller, etc.) and

separated from core CPU functionality in a network device, such that the link integrity module may remain powered in a cold power mode (e.g., when core functionality is powered down). The separately powered data-based link integrity module is powered by an auxiliary backup power source (e.g., often referred to as V_{aux} in PC centric applications). Thus, when in a power down mode (e.g., when in an ACPI defined D3 type cold state) a minimal D3 power source may be used to power the separate link integrity module separate from the power source to the core network device functionality.

10 In accordance with the principles of the present invention, the separately powered data-based link integrity module may be redundant to a software driver type data-based link integrity module implemented in core memory and enabled or disabled as desired. Alternatively, the separately powered data-based link integrity module
15 may be in lieu of the otherwise conventional software driver implemented in core memory and permanently enabled.

While the present invention is described with reference to embodiments relating to Home Networking devices (e.g., to HomePNA™ network devices), the principles of the present invention relate equally to
20 other networks that otherwise conventionally use driver or software data-based link integrity techniques which would otherwise become non-functional as a result of a system power down, e.g., D3 type cold state.

Fig. 1 shows a separately powered hardware link integrity module which remains powered when the network device is powered down, e.g., in a D3 type cold power state, as well as a software link integrity module in core memory which is lost during a power down, either of which are switched in as desired, in accordance with the principles of the present invention.

In particular, as shown in Fig. 1, a network device **150** such
30 as a HomePNA™ network device includes a core processor **102** and core

memory **104**. The core processor **102** and core memory **104** may be integrated into a common device, or may be separate devices. The network device **150** further includes a link interface **106**.

The core memory **104** of the first embodiment shown in Fig. 1 includes a software driver **110** having link integrity functionality. However, importantly, a hardware implementation **100** is also implemented. In the disclosed embodiment, either the hardware link integrity module **100** or the driver software link integrity module **110** is enabled (e.g., by the power mode control module or other suitable configuring device), and the enabled link integrity device **100** or **110** is functionally switched into operation (as depicted figuratively by switch **171**).

'Hardware' implementation of the link integrity module **100** refers herein to a device which is separate in hardware from the core memory **104**. The hardware link integrity module **100** may be formed from logic gates, a state machine, or even a separate processor (e.g., a low power microcontroller), so long as the hardware link integrity module **100** is powered separate from the core memory **104**.

Thus, in accordance with the principles of the present invention, a separately powered hardware based link integrity module, either in addition to or in lieu of an otherwise conventional software driver based link integrity module, is implemented such that the separately powered hardware link integrity module maintains power during a D3 type cold state.

In Fig. 1, the hardware link integrity module **100** is shown as being permanently tied to D3 power, while the core memory is powered from a system power source. When the network device **150** is powered down to a D3 type cold state, system power is removed from the core memory **104** (albeit after an arranged power down procedure has been performed), but the D3 power source remains. In this way, the hardware

link integrity module **100** continues to provide link integrity information to other network devices over the link interface **106** while the remainder of the network device (e.g., the core processor **102**, core memory **104**, etc.) are powered down).

5 Thus, the hardware link integrity module **100** may be continuously powered by a backup power source such as a D3 power source **191**. Alternatively, the hardware link integrity module **100** may be switchably powered from the system power source when the network device is fully functional (i.e., in a non-powered down mode) and switched
10 to be powered from a backup power source when the network device is powered down. Preferably, but not necessarily, the switchover in power sources to the hardware link integrity module **100** is uninterrupted to minimize disruption to the network when the network device powers down and/or up.

15 The hardware link integrity module **100** and the software driver link integrity module **110** are each separately capable of determining whether or not the network device is able to receive frames from at least one other station on the network. In the absence of other traffic, the enabled link integrity module **100** or **110** periodically transmits a
20 data-based link integrity signal, e.g., a Link Integrity Control Frame (LICF) to a Broadcast MAC address. The interval between such transmissions may be governed by a specification or standard.

 Accordingly, wake up data (e.g., a pre-defined system wake up data packet) may be sent to a network device recognized to be in a
25 powered down or un-powered state (e.g., in a D3 cold state). Otherwise, the Destination Address of the desired network device would need to be sent as in the formation of a "normal" packet (i.e., as if it were in a state other than in a powered down state).

 Thus, using a separately powered and power-down enabled
30 hardware link integrity module **100** in accordance with the principles of the

present invention, networks and network devices are made to be more robust in a fully functional state. For instance, if a link integrity signal is not transmitted while a device is in a D3 type cold, un-powered state, other network devices on the network would otherwise assume that the network device is no longer functional and off the network (at least until re-powered through means other than data-based communications, which would not be possible in a powered down mode), and thus would not further attempt to access that particular network device.

In all power states other than the D3 cold power down state, link integrity may be handled by the software link integrity module 110, and the hardware link integrity module 100 may be disabled to conserve its power source (e.g., a backup D3 or auxiliary power source). Preferably, information is passed between the software link integrity module 110 and the hardware link integrity module 100 to allow for a smooth transition between handling of link integrity by the hardware link integrity module 100 during D3 type cold power down states, and handling of link integrity by the software link integrity module 110 during non-D3 type power down states.

In networks that are rate adaptive, e.g., HomePNA version 2.0, the link integrity modules 100 or 110 preferably has prior knowledge of the minimum accepted Payload Encoding value negotiated by all of the network devices currently residing on the network, and the link integrity data packet is preferably transmitted at this negotiated rate.

According to the disclosed embodiment in a HomePNA network, in the ACPI D3_Cold state, the hardware link integrity module 100 performs link integrity during this state. The valid packet data to be transmitted is preferably written into a packet buffer structure or holding register by the driver software link integrity module 110 prior to its being disabled in response to a D3 cold power down request. The hardware link integrity module 100 then preferably transmits this packet upon expiry of a

link integrity timer. Link integrity information may be transmitted, for example, at the lowest common encoding rate. In a HomePNA application, it is beneficial to assume that link integrity is transmitted at an encoding rate of 2 bits/ baud by network devices in D3 type cold power down or inactive states because the rate that is receivable by all network devices actively listening to a broadcast address may change during the course of being in this state. Furthermore, transmission at 2 bits/ baud is beneficial as it may be the lowest common receive rate supported by all network devices actively listening on the network.

Fig. 2 is similar to Fig. 1 but shows implementation of only a separately powered hardware link integrity module **100** which remains powered when the network device is powered down, in accordance with another embodiment of the present invention.

In particular, as shown in Fig. 2, the driver software link integrity module **110** shown in Fig. 1 is eliminated, and a hardware link integrity module **100** is permanently enabled. While the hardware link integrity module **100** is shown as being permanently powered by D3 backup power, power to the hardware link integrity module **100** may be switched to system power when the network device **250** is in a non-powered down state.

Fig. 3 is an exemplary system behavior state flow diagram of the embodiment shown in Fig. 1.

In particular, as shown in step **202** of Fig. 3, the D3 state is determined. If the network device **150** is in the process of going into a D3 power down state, then the process flows to step **214**, which disables the software link integrity module **110**. If, on the other hand, the network device **150** is not in a D3 type powered down state, the process flows to step **204**.

Step **204** allows disabling of the hardware link integrity module **100** to provide otherwise conventional link integrity functionality

from only the software link integrity module **110**. This is accomplished by steps **210** and **212**.

Step **206** disables the software-based link integrity as well as the hardware-based HPNA version 2.0 link integrity generator.

5 Step **208** also enables the HPNA version 1.0 link integrity generator.

On the other hand if the hardware link integrity module **100** is not to be enabled (e.g., otherwise conventional functionality is to be performed), the process flows to step **210** which enables the software link integrity module **110** and to step **212** which disables the hardware link integrity module **100**.

In a HomePNA network, older legacy devices using physical link integrity signaling (e.g., HomePNA version 1.0) may exist together with newer devices using data-based link integrity signaling (e.g., HomePNA version 2.0). For instance, in isolated HomePNA networks with HomePNA version 1.0 (V1) terminals, the link integrity signaling is transmitted in V1-defined physical signaling parameters. This physical signaling mode is not consistent with later generation network devices (e.g., HomePNA version 2.0 (V2) terminals). Both systems, however, employ and implement data-based link integrity signaling.

If the environment is a mixed network and the D3 power down state is FALSE (based on step **204**) then the process flows to step **206**.

If the D3 cold state is to be entered, the process flow is via step **214**. Referring to step **214** of Fig. 3, a D3 cold state is entered with link integrity maintained through the hardware link integrity module **100**, rather than through the software link integrity module **110** in core memory **104**.

In step **216**, it is determined whether or not legacy devices exist on the network, requiring alternate type link integrity (e.g., version

1.0 HomePNA). If so, link integrity including legacy signaling capability is enabled (step **220**) while disabling packet based version 2.0 HomePNA link integrity signaling (step **218**). Otherwise, the hardware based version 2.0 HomePNA link integrity signaling is enabled (step **222**) and the legacy supporting link integrity is disabled (step **224**).

Link integrity generation and special state handling is considered in Fig. 4, which is an exemplary transmitter behavior state flow diagram showing backwards compatibility with a physically unique electrical signal based link integrity system (e.g., HomePNA version 1.0) in a network device implementing data-based link integrity (e.g., HomePNA version 2.0), in accordance with the principles of the present invention.

In particular, as shown in step **302** of Fig. 4, logic in the hardware link integrity module **100** determines whether or not link integrity information is to be transmitted. If the device is inactive, link integrity information should be transmitted to indicate to other network devices that the relevant network device is still present.

Step **302** also looks to see if any legacy network devices exist in the network (e.g., HomePNA version 1.0 devices). If so, as determined in step **304**, then the data-based link integrity signaling packet is preferably transmitted using a form including physical integrity signaling, so that both physical link integrity and a relevant link integrity data packet are transmitted, as shown in step **306**. If not, then only data-based link integrity packet information need be transmitted, as shown in step **308**.

Alternatively, to provide compatibility with network devices utilizing only physical link integrity signaling (e.g., as in HomePNA version 1.0), a physical based link integrity pulse may always be transmitted to other network devices regardless of the current system power state.

While the invention has been described with reference to the exemplary preferred embodiments thereof, those skilled in the art will be

able to make various modifications to the described embodiments of the invention without departing from the true spirit and scope of the invention.

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